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Space Human Factors Engineering Project

Implementation Plan FY 2002 – FY2003

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National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, TX 77058

Space Human Factors Engineering Project Advanced Human Support Technology Program

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APPROVALS

Dane Russo _____ Date_____

Manager, Advanced Human Support Technology Program

Thomas W. Rathjen _____ Date_____

Manager, Space Human Factors Engineering Project

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1. NASA Research Announcement and Technology Development Projects Titles and Principle Investigators

1. Introduction and Background

This 2002 – 2003 Space Human Factors Engineering (SHFE) Project Implementation Plan is a companion document to the SHFE Project Plan. The Implementation Plan seeks to specify deliverables for FY2002-2003 and a long-range strategy. By way of background, this document also contains brief overviews of the SHFE Project, the Project Plan and the past year's accomplishments.

"The human being must be integrated into the space mission in the same way in which all other aspects of the mission are integrated. A comprehensive organizational and functional strategy is needed to coordinate engineering and human needs." (Institute of Medicine report to NASA, 2001)

2. SHFE Project Overview

The SHFE Project aims to coordinate the transfer of human factors knowledge and technology from basic research through applied research to the opportunities for implementation in NASA human space flight programs. This transfer is facilitated by the provision of grants to selected researchers and the implementation of communication mechanisms such as conferences, workshops, teleconferences, seminars and site visits.

The Human Factors discipline overlaps with many other communities including engineering, medicine, physiology, psychology and operations management. Consequently the SHFE Project members interface regularly with researchers and practitioners in these companion disciplines, both within and outside NASA. The activities of the SHFE Project members range from such topics as basic research on human vision, modeling and biomechanics to applied research and development of analysis tools and design requirements to support human space flight. The operational challenges that attract the attention of human factors specialists include such diverse topics as space vehicle layout, space suit design, controls and displays, labeling, communication facilities, distributed team structures, emergency medical procedures and crewmember activity scheduling. The media for these research and development activities are also varied. They include specialized laboratories, space flight analogs, training simulators and operational space vehicles. Much of the current focus attempts to predict the behavior and performance of crewmembers and their support teams on long duration missions by extrapolation from current short and intermediate duration experiences.

3. The SHFE Project Plan

The SHFE Project is guided by documents such as the Bioastronautics Critical Path Roadmap (2000) and the National Research Council's Report on Space Human Factors (1997). The SHFE Project Plan articulates those human factors research, development, communication and implementation activities that will assure the effectiveness, efficiency and safety of human space flight missions. It describes the related

organizational context and management processes within NASA and the two major activity pathways:

- The NASA Research Announcement (NRA) process solicits proposals, regarding basic human factors research, from researchers in universities and NASA. The NASA SHFE project leadership participates in developing the content of these solicitations and in the review of the proposals for relevance to the NASA mission. The proposals are peer reviewed by external human factors experts. Typically these projects address Technology Readiness Levels (TRL) 1, 2, 3, but on occasion may result in tools and techniques at higher TRLs. (see section 18 of the Project Plan for a detailed description of TRLs)
- Technology development projects (TDPs) facilitate mid level technology advancements (TRL 4, 5, 6) and address topics and technologies that have a good chance of near term application to the space program. NASA Space Human Factors specialists generally carry out these projects, but collaboration with external (university and other government laboratory) personnel is permitted given that the project is clearly defined as technology development rather than basic research.

Both NRA and Technology Development projects may be flight, simulator, analog based.

4. SHFE Project Management

The SHFE Project is one element of the Advanced Human Support Technology (AHST) Program. The management of the SHFE Project is accomplished through the coordinated activities of the SHFE Project Manager, the Deputy Project Manager, the Deputy Project Manager for Ames Activities, the Discipline Coordinating Scientist and representatives from NASA HQ. A Science and Technology Working Group (STWG) supports the activities of the SHFE Project. The activities of the SHFE project include management of the research and development activities, involvement with project customers within NASA and participation in outreach activities with universities, industry, other government organizations and public forums. General and targeted activities of the SHFE project management team occur regularly, through face-to-face meetings and teleconferences.

Specific plans for SHFE Project Management in FY 2002 include:

January

- Attendance at the NASA SHFE Biennial Workshop (or Biennial Bioastronautics Workshop)
- Site Visit to NASA JSC
- Discussion of the Technology Capabilities Roadmap
- Discussion of Integration Opportunities

February -April

- Support NRA peer review process
- Strategic planning

April / May (Teleconferences)

- Review of NASA Planning Documents and Technology Development Project (TDP) solicitation plans

July/August

- Site visit to NASA Field Center
- Discussion of Outreach opportunities
- Review of new Technology Development Project Proposals (if solicited)

September / October

- Human Factors and Ergonomics Society Annual Meeting
- Strategic planning meeting

Monthly

- SHFE PI teleconferences
- AHST teleconferences

FY2003 plans will be added in the next revision of this document

5. FY2000 - FY2001 Activities

5.1 Requests for Proposals

During CY2001 three requests for (Human Factors) proposals were issued through the Office of Biological and Physical Research:

- NRA Flight Based Research (11 Proposals submitted, funding decisions pending)
- Technology Development Projects (TDP) (11 Proposals submitted, 7 funded)
- NRA Ground Based Research (Solicitation November 2001)

Details of the NRA solicitations may be found on the OBPR website:

http://research.hq.nasa.gov/code_u/code_u.cfm

5.2 Reporting

Lists of the ongoing NRA projects and Technology Development projects may be found in Appendix 1. Updates regarding the status of each of these projects occurred through the media of the 2001 NASA Bioastronautics Workshop, regular teleconferences and site visits by members of the SHFE project management team. Principal Investigators make annual submissions to the NASA Office of Biological and Physical Research “Task Book” detailing their progress and products such as refereed publications:

http://research.hq.nasa.gov/code_u/code_u.cfm

The NASA Space Human Factors management team regularly conducts teleconferences for both NRA and TDP projects. These teleconferences serve to resolve administrative issues and to provide the opportunity for cross-fertilization among researchers. The use of real time electronic data links allows the concurrent presentation of detailed project information.

The major reporting opportunity occurred at the Second Biennial Space Human Factors workshop, which was held on January 23rd and 24th in Houston. In alternate years reporting will be through the Biennial Bioastronautics Workshop. Details of the 2002 workshop, including the proceedings, may be found at:

<http://www.dsls.usra.edu/dsls/meetings/shfp/>

The mandatory final reports and expected peer review and technical publications address the broad goals of the NASA Bioastronautics organization together with earth benefits / spin offs and educational outreach material.

6. FY2002 – 2003 Implementation Strategy

The aim of the 2002 and out year activities is to pay specific attention to the optimal use of university, NASA and other government human factors expertise, laboratories, analog environments, the Space Shuttle and the International Space Station as opportunities to measure and optimize human responses to habitability, workplace, equipment, information system and procedures in long duration space flight. This focus will be reflected in NRA and Technology Development project solicitations as well as efforts, recommended by the STWG, to refine the pipeline from research to application. This will be accomplished by increasing the number and depth of opportunities for communication and collaboration between university and NASA researchers. Specifically, the Biennial Workshop provides the opportunity for face-to-face interaction between Human Factors researchers, practitioners, customers, managers and the STWG members. Efforts will also be made to increase the opportunities for site visits and collaboration among universities, NASA field centers and other government laboratories.

The SHFE content in the Bioastronautics Critical Path Roadmap addresses the following general questions, each aimed at a particular aspect of human response to system design in the context of long duration space flight that may compromise mission success:

1. What information, interface and training systems will support the crew's ability to operate with varying levels of support from earth sources?
2. What workload schedules will enhance crew performance and mitigate adverse affects of the space environment?
3. What methods of assessing human performance capabilities will be most useful?
4. What aspects of system and habitat design will best enhance human performance in extended duration space flight?
5. What theoretical, analytical and computational models will be of most value in the context of design and evaluation of systems for long duration space flight?

During 2001 these general areas were broken down into narrower research areas and then again into specific research questions. A list of these details is available on request.

6.1 SHFE Research (NRA) Projects

A profitable theme for the coming years will be an emphasis on Human Performance Analysis, Design, Decision and Digital Modeling Tool Development. Such a theme will cover the gamut of physical, informational, environmental and psychosocial aspects of human performance. Specifically the following analysis tools and model development and applications should be addressed:

1. Anthropometric models, including micgravity changes and relationships with space vehicle, equipment and clothing applications.
2. Biomechanical – static and dynamic kinematic and kinetic models especially focused on the effects of different gravitational loads.

3. Cognitive models, including models of human system interactions, situation awareness and (naturalistic) decision making under uncertainty
4. Motor behavior and performance – specifically these models will address the effects of micro gravity, restraints and restrictive suits on crewmember’s ability to perform required motor functions
5. Communication and control models – models of human and machine communication and collaboration in the control of complex systems under informational, temporal and environmental constraints
6. Environmental models – modeling of the physical environment (heat, light, noise and vibration) and its effects on human behavior and performance
7. Psycho-social factors – models that assess human performance in the context of closely confined and distributed teams working under stressful conditions, workload and scheduling models related to long term space flight
8. Integrated human factors models and evaluation methods that address behavior, performance and system design, habitability, environmental and organizational factors that predispose to human related mission outcomes (both positive and negative).

Such tools and models will need to be populated with relevant evidence and supported by appropriate policy statements regarding accommodation and risk- benefit. These modeling themes will form the basis of the next round of NRA solicitations

6.2 SHFE Technology Development Projects (TDPs)

6.2.1 Current TDPs

Currently there are nine Technology Development projects underway each aimed at near term deliverables related to the critical questions outlined above. The 2002 deliverables for each project are listed below. The 2003 and out year deliverables will be added in the next revision of this document.

- Space human factors engineering database - Cletis Booher - JSC
 - Agreement of participation by subject matter experts
 - Review existing requirements
 - Database development
 - Identify sources for additional information
 - Draft new requirements
 - Workshops
- Development of an index of habitability using converging indicators - Patricia Cowings - ARC
 - Hardware and software development
 - Analysis of Command and Control Vehicle data
 - Test and evaluate neural networks
- Astronaut scheduling assistant: a biomathematical model of the neurobehavioral performance capability of space shuttle crews. - Melissa Mallis - ARC
 - Specification of mathematical model

- Literature review
 - Workshop
- Development of analytical tools to process and apply digitally scanned anthropometric data - Suhdakar Rajulu - JSC
 - Evaluation and conversion of Natick's library routines
 - Development of analytical software
 - Identification of appropriate anthropometric variables
- Malleable human interfaces (MHI) - Dane Russo - JSC
 - Complete MHI notional caution and warning interfaces
 - Complete caution and warning information system performance measurement and data collection
 - Analyze project research results
- Imagery systems for enhanced crew habitability, performance and productivity on the ISS - Mihriban Whitmore
 - Functional requirements development
 - Technology review
 - Analog testing
- Multipurpose crew restraints for long duration space flight - Mihriban Whitmore - JSC
 - Focus groups
 - Concept development
- Emergency medical procedures on the ISS - Mihriban Whitmore and Tom Marshburn - JSC
 - Functional requirements development
 - Interview / task analysis question development
 - Evaluation of current ISS medical procedures
 - Test plan for select scenarios
- An Integrated human factors evaluation process for space payloads and equipment. - Mihriban Whitmore - JSC
 - Identification of candidate cases
 - Root cause analysis of human factors problems
 - Converge on evaluation process

6.2.2 Strategy for Future TDPs

6.2.2.1 Tool Development

A tool development strategy, involving Technology Development Project selections will pave the way towards a shift from the expert driven - reactive mode of operation of the NASA SHFE practitioner community to a proactive mode of operation.

6.2.2.2 Training Material

A complementary strategy will be the development of SHFE training material that can be deployed to the NASA and contractor internal customers, including: engineering, mission operations, crew office, program office, safety and life sciences.

6.2.2.3 Human Factors Models

A specific Technology Development Project for FY 2003 will be the evaluation of a wide spectrum of Human Factors models and their 'population' with NASA relevant data and policy/risk/benefit overlays.

6.2.2.4 Outcome Driven Metrics

The establishment of outcome driven metrics, using a common communication currency will improve the effectiveness and efficiency of the NASA SHFE process, as it is often difficult to communicate effectively the importance of human factors requirements in comparison with other major mechanical and medical challenges. Particular attention will be paid to system and activity design factors that have serious implications rather than simply addressing the cumulative effects of lack of comfort, convenience and habitability. It is anticipated that these habitability and performance models will be developed to produce quantitative risk/benefit predictions and design guidelines. In addition the NASA Standard 3000 - Man-Systems Integration Standards will undergo a major overhaul to update its content and improve its usability through web access.

6.2.2.5 Human - System Evaluation Process / Opportunistic Data capture

Currently, there is no formal process for the passive extraction of opportunistic human factors information involving naturalistic behavior and performance. Such evidence exists through the media of routine downlinks, debriefs, video and so on, but "data mining" of this information is not routine.

A potential TDP might be to formalize the process of opportunistic data capture, analysis and modeling of crew (and support staff) activity and performance. An example project would include micro gravity motion analysis and the use of restraints and mobility aids. A second example would involve the monitoring of communications to obtain crewmember activity-sampling data for comparison with planned schedules. Other examples will be the use of computer based data mining to extract common themes from

routine and other communications that would address both system and organizational design issues. The key to such a process is that it is both non-invasive and does not cause interference with the natural activities and performance of the experimental subjects.

6.2.2.6 ISS Productivity

Human Factors analysis and design methods can be brought to bear on the improved health, safety, and well being of crewmembers and on the quality and productivity of their efforts. TDPs will be developed to increase productivity by removing barriers, reducing excessive training demands, and improving procedures, processes, and interfaces. Efforts will be made to improve the sophistication of activity scheduling while increasing levels of crew autonomy. The development of an objective habitability index will further enhance NASA's ability to manage the operational context of space science.

6.3 Flight / Earth Analog / Other Ground Based Research and Development Opportunities

The human factors community, in US Universities and NASA, is well endowed with laboratories for narrowly focused research and development. The community also avails itself of opportunities to extract data from flight programs, simulators and earth analogs. Developments of Virtual Reality devices abound. However, such efforts tend to be isolated rather than integrated with other human factors information needs. For example, the SHFE research, development and practitioner specialists have relatively little interaction with the training community who make extensive use of analogs and simulators.

6.3.1 Identification of Research and Development Media

An effort will be made to identify the many analog and simulation facilities in NASA, Department of Defense and Universities that could be the focus of collaborative research and development projects. Particular attention will be paid to the many training facilities that are a rich source of human performance data.

6.3.2 Collaboration Incentives

Collaborative activities are often a challenge as individual institutions commonly seek to maximize their own involvement and income. However, specific grant solicitation wording can encourage proposals that involve collaboration and thus make the best use of physical and expertise resources.

A specific plan for FY2002 - FY2003 will be the identification of those collaboration opportunities that are potentially available to provide rich human factors performance evidence and to link these facilities with questions from the Critical Path Roadmap. Proposal solicitations will include specific collaboration encouragement.

6.4 Integration Activities

NASA Space Human Factors faces the challenge of connectivity and an effective pipeline between basic research, technology development and evaluation, and practice. The grant proposal review and refereed publication processes can lead to a “reductionist” trend, with peer-reviewed publication as the principal output. One cause of lack of integration is that, although Human Factors Engineering overlaps technically with many other disciplines, it may be excluded where specialist expertise is found in other organizations. Examples are found within NASA in safety, exercise physiology, training, robotics development and crew activity scheduling. The following specific opportunities can be exploited to facilitate this human factors engineering integration role.

6.4.1 Workshops, Seminars and Visits

A formal schedule will be implemented of targeted workshops, seminars and reciprocal site visits to open the doors for communication and common understanding regarding SHFE knowledge and opportunities among basic and applied researchers, practitioners, customers and managers. The Second Biennial Space Human Factors Workshop is a model for such activity. The necessary precursor of such a strategy will be through the formalization of technical interest groups during FY2002 - FY2003. The Biennial Bioastronautics Workshop will provide another opportunity for the development of such communication opportunities.

6.4.2 Internet and Intranet

A second approach, discussed at recent NASA sponsored workshops on organizational risk and organizational learning, identified the Internet and Intranet as important technological opportunities. Targeted application of these Internet / Intranet opportunities will be made to the challenges of communication within the NASA Space Human Factors context. The development of an electronics version of the Space Human Factors database through a Technology Development Project will form the basis of such activities. Also the January 2002 NASA SHFE Workshop has employed a principally electronic format that could be developed to support targeted technology development teams.

6.4.3 Targeted Teleconferencing and Distributed Teams

At the minimum, greater efforts will be made to exploit the facilities of targeted video and voice teleconferencing. Over the past year such approaches have been used with some success to enhance communication within NRA, TDP, and STWG groups.

6.4.4 Personnel Strategies

The most powerful strategy of facilitating the translation of research findings into useful and useable applications involves more formal attention to the funding and personnel assignment processes. These issues were addressed in the recent NASA SHFE STWG recommendations. Personal, personnel and logistic issues are often cited as barriers to such activities. Recent experience of collaboration between NASA JSC and ARC scientists and practitioners in the area of STS vehicle displays attests to the benefits of this strategy.

The SHFE management will pursue the possibility of addressing the knowledge gaps between practitioners and researchers by the development of short or medium duration training courses and their link to a broader educational strategy, such as a higher degree program in Human Space Systems Engineering. Such an approach is widely used in some areas of academia and in most large business organizations.

At the research solicitation and funding level greater efforts will be made toward the writing of requests for proposals, technical and relevance reviews and follow through to applications by including clauses that encourage collaboration.

6.5 Inreach Activities

A common challenge for human factors applications is that there are always too many opportunities and too few human factors specialists. Furthermore the implementation of change is rarely the prerogative of human factors specialists, who generally act in an advisory capacity to engineers, mission controllers and program planners. Many human factors communications are embodied in complex requirements documents (e.g. NASA-STD-3000) that require interpretation by human factors specialists and commonly involve dealing with requests for waivers. Efforts will be made to eliminate these barriers to human factors applications through the following strategies:

6.5.1 Common Currency

A strategy to resolve these difficulties is to develop a formal process of human factors communications that facilitates requirements communication, verification and validation. These concepts of "common currency" and "common requirements format" are currently being developed through operational support to the ISS and will be evaluated during the coming year.

6.5.2 Training

These analysis tools, decision rules and design guidelines require the complementary development of internal training material so that the users of human factors information can use them. Such an approach will allow a large proportion of human factors issues to be addressed by non human factors specialists, leaving the human factors specialists to

work on tool development, training and the resolution of particularly complex human factors challenges.

6.6 Outreach Activities

A mandate for government-sponsored research and development in general and NASA sponsored research and development in particular is the transfer of knowledge and technology among the education and private sectors. The common formal method of outreach is through routine involvement at academic, technical and professional workshops, seminars and conferences. Also there is a plethora of opportunities for publication in peer reviewed and professional journals. Other publication media include the production of books, pamphlets and educational material aimed at all academic, age and interest levels. NASA has great experience of such activities through the Smithsonian Institute Air and Space Museum, the various exhibits and tours at NASA Field Centers and the well-established “Space Camps.”

A strategy for the coming years will be to articulate a plan for such outreach endeavors to deploy space human factors knowledge to universities, schools and the public at large. Specifically the following initiatives will be undertaken by NASA supported SHFE researchers and practitioners:

1. Presentations at Human Factors and related conferences
2. Encouragement for peer reviewed publications
3. Development of curricula for space human factors content in university, school and continuing education arenas
4. Development of Web based educational material
5. An introduction of design competitions addressing space human factors activities

Appendix 1

NASA Research Announcement and Technology Development Project Titles and Principal Investigators

Name	Institution	Research Title	NRA / TDP	Completion Date
Badler, Norman Ph.D.	U. Pennsylvania	Performance Assessment Using Dynamic Simulation and Human Factors Analysis in IVA and EVA (HEDS 01)	NRA	7/04
Caldwell, Barrett Ph.D.	Purdue University	Control-Crew Network Communication during Routine and Non-Routine Events: Effects on Mission Control- Crew Performance HEDS96	NRA	9/02
Clancey, Bill Ph.D.	Ames	Integrated Simulation of BIO-Plex Work Practices and Systems	NRA	3/02
Haney, Lon	Idaho National Engineering & Environmental Lab	Application of the FRANCIE Framework and Methodology to Assessing to Human Reliability and Enhancing Human Performance in Aerospace Maintenance, Safety and Crew Operations HEDS 98	NRA	6/02
Neumann, Ulrich Ph.D.	U. Southern Calif.	Augmented Reality for Space Flight (HEDS 99)	NRA	12/02
Newman, Dava Ph.D.	MIT	Quantifying Astronaut Tasks: Robotic Technology and Future Space Suit Development (HEDS 98)	NRA	3/02
Nitzan, David Ph.D.	SRI International,	Telepresence human factors for glove box experiments (HEDS 99)	NRA	2/03
Oman, Charles (Chuck) Ph.D.	MIT	Advanced displays and controls for 6 DOF orientation and navigation in virtual 0-g (HEDS96)	NRA	6/02
Schlegel, Robert Ph.D.	U. of Oklahoma	Integrated Crew Performance Assessment and Training	NRA	12/03
Zamorano, Lucia M.D.	Wayne State Univ.	The development and human factors analysis of advanced 3-D visualization for telepresence (HEDS 99)	NRA	1/03
Booher, Cletis	JSC	Space Human Factors Engineering Data Base	TDP	10/03
Cowings, Pat Ph.D.	Ames	Development of an Index of Habitability Using Converging Indicators: Physiology, Performance, and Subjective Reports	TDP	12/04
Mallis, Melissa Ph.D.	Ames	Astronaut Scheduling Assistant: A Biomathematical Model of the Neurobehavioral Performance Capability of Space Shuttle Crews	TDP	12/04
Rajulu, Sudhakar Ph.D.	JSC	Development of Analytical Tools to Process and Apply Digitally Scanned Anthropometric Data	TDP	12/04
Whiteley, James Ph.D.	JSC	Malleable Crew Interfaces	TDP	9/02

Whitmore, Mihriban Ph.D.	JSC	Imagery Systems for Enhanced Crew Habitability, Performance and Productivity. Multi-Purpose Crew Restraints for Long Duration Space Flights Emergency Medical Procedures on ISS	TDP	12/04
Whitmore, Mihriban, Ph.D.	JSC	Multipurpose Crew Restraints for Long Duration Space Flights	TDP	12/04
Whitmore, Mihriban, Ph.D.	JSC	Emergency Medical Procedures on ISS	TDP	12/04
Whitmore, Mihriban, Ph.D.	JSC	Development of an Independent Human Factors Evaluation Process for Space payloads and Equipment	TDP	12/04